Report on migration of Butternut Creek in Wheeler’s field

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INTRODUCTION

**Project Overview**

This report summarizes the activity of a meander loop of Butternut Creek. The channel has been migrating laterally over the last several decades. The report gathers information about channel location over time using aerial imagery and elevation data sets from government agencies, and provides a new highly detailed image and elevation survey using pictures taken with a camera mounted on a remote controlled helicopter provided by SUNY Oneonta’s Biological Field Station in the summer of 2015. In brief, the channel moves laterally about 0.1-1.7 m per year, and has done so at least since the early 1990s. Trees planted by Otsego County Soil & Water District in 2012 are unlikely to grow fast enough to stabilize the bank before being eroded by Butternut Creek.

There are several reasons to perform a new survey of the area. First, while high quality elevation data exist for this area, those data were collected in 2007. The channel has migrated over that time, and another high resolution elevation survey would highlight changes over that time. The new survey would also serve as a new baseline against which future measurements could be compared.

Second, in the last ten years, two very large flood events have hit the region--one in 2006 (several days of heavy rain) and another in September 2011 as remnants of Tropical Storm Lee moved through the area. There has been some concern about the potential for the frequency of large storm events to increase due to global warming. Frequent detailed documentation of the channel shape could supply the information needed to assess the effects of flood size on bank erosion, and thus provide watershed managers with better insight into potential problems with erosion under a changing climate.

Additionally, from a basic science perspective, we would like to know what the main or dominant erosion mechanisms are for this river. The mechanisms which erode banks include bank collapse due to stream undercutting of a bank; soil heave from frost needle growth during freeze-thaw events in winter; fluid shear stress on the soil particles in the bank during flood flows; burrowing, digging, path development etc., by animals; and small mass flows of water and sediment on cutbanks during saturating events (but still above the water level in the creek). Which of these mechanisms is most important in overall erosion is not well known. It could be that concern about increased erosion from larger floods is not warranted, if fluid shear stress, for instance, is not a significant erosive agent. For instance, bank collapse could be most responsible

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for bank retreat, and thus undercutting mechanisms become very important. It might be that smaller and more frequent flows that are still capable of eroding the base of the cutbank play a more important role in driving migration via bank collapse than larger less frequent flows do via bank shear. Repeat high resolution measurement of stream banks are required to address these uncertainties.

**Geomorphic setting**

The Wheeler farm extends from upland ridges down to the valley bottoms along Butternut Creek (see Figure 1). Landforms within the confines of the farm include a bedrock gorge with waterfalls; a perennial tributary creek which has built a modern alluvial fan into Butternut Valley; older and higher alluvial fans perched on the valley side, presumably formed by the same tributary during a time when a glacier was still filling part of the main valley bottom; old flow paths of now defunct streams in the main valley of the Butternut; and a modern floodplain etched with flood channel and meander scars--a few of which hold oxbow lakes. The latter in particular are diagnostic of laterally migrating meander loops in Butternut Creek, and they both highlight where the channel used to be, and speak of “behavior” which has persisted over longer times--from tens to hundreds or thousands of years. Both the old alluvial fans and the floodplain are actively farmed. The floodplain in particular is of high agricultural value, with a soil consisting of silt, sand, and minor amounts of clay.

![Figure 1. Shaded relief map of Butternut Valley including Wheeler’s farm, derived from NYSDEC’s lidar elevation data from 2007.](image-url)
Flood Records for Local Rivers

Butternut Creek was monitored by the United States Geological Survey (USGS) up through the mid 1990s, but those data are no longer easily available. In place of actual discharge measurements for the Butternut, the USGS stream gage on the Unadilla River at Rockdale, NY downstream from Wheeler’s farm serves to approximate the stream flow in the Butternut. Figure 2 shows the daily discharge record from 2003 up to early July 2015. The two largest floods ever recorded for the Unadilla River occurred in June 2006 (unnamed summer storms) and September 2011 (Tropical Storm Lee). Note that the discharge scale in the figure is shown in a logarithmic scale, which reveals the spectrum of sizes of daily flows.

![Daily discharge record for Unadilla River at Rockdale, NY](image)

Figure 2. Daily discharge record for Unadilla River at Rockdale, NY from the USGS.

In the past decade there have been about 7 days when discharge in the Unadilla River matched or exceeded 10,000 cfs. Such flows, when viewed over the entire record for the Unadilla River, are exceeded on 50 days out of 27,967 days of record (76 years). Are these the flows that erode the most, or are smaller more frequent flows more effective in modifying the channel? What flow size is appropriate to monitor? We would like to answer these questions, and they can only be answered with detailed measurements of the river bank over time. This study gathers what we know from prior surveys, and lays the groundwork for future work to fill in gaps of our understanding about erosion and deposition along Butternut Creek.

Past surveys

As a neighbor of the Wheelers, one of the authors, Les Hasbargen, has had the opportunity to visit Wheeler’s field along Butternut Creek on numerous occasions throughout each year since 2007. Numerous photographs taken over this time period can be used to qualitatively estimate effects of various floods and note erosion processes visible at the cutbank. Photos were typically taken of the area from the field or from a watercraft on Butternut Creek. The photos in most cases are merely suggestive of change (for example, revealing a recent bank collapse). In a few cases however, the photos were taken with significant overlap in the field of view, and thus are amenable to 3D object reconstruction using photogrammetric software. In addition to those photos, a detailed land survey with differential GPS receivers was conducted in 2013 to map trees planted along the bank, and the location of the top of the cutbank as well. Other excellent sources of information on channel location over time include orthophotographs and topography available from New York State’s Department of Environmental Conservation website. The aerial photos were taken every several years, and extend back to 1994. For topography, NYS DEC teamed with US Federal Emergency Management Agency to collect high resolution topography using light...
ranging and detection (lidar) equipment in 2007--after the then flood of record of June 2006 (which was exceeded by the flood from Tropical Storm Lee in 2011). We gathered these aerial image data sets and determined changes in bank location from one data set to the next.

**SWCD tree plantation**

In 2012, Otsego County Soil and Water Conservation District (SWCD) implemented a channel stabilization program which planted 7000 trees along unstable channel banks for 33 landowners throughout the county. A total of 242 young trees were planted along active cutbanks on the Wheeler property along Butternut Creek, a few miles south of Morris, NY (Figure 3). Plantings comprised oak, maple, elm and willow. The trees were staked and tubed with plastic netting. The presumed goal of the treeplanting campaign was to reduce erosion of the stream bank by anchoring the soil in place through the growth of tree root networks. In 2013, the tree locations were surveyed by Les Hasbargen with a total station, and georeferenced using a differential GPS system, Magellan’s ProMark 3. A map of these locations appears below. By 2015, some of the trees were in danger of falling into the creek as the cutbank migrated west.

![Figure 3. Tree seedling locations along Butternut Creek on Wheeler’s farm. Note that two rows of trees were planted in 2012, and only the row closest to the field was surveyed in 2013. Aerial image taken in April 2014 and provided by New York State Department of Environmental Conservation.](image)

**METHODS**

**2015 Aerial survey with remote controlled aircraft**

In the last ten years, there has been a very rapid development in the use of small remotely controlled aircraft for aerial imagery and for the recovery of high resolution topography (Pierzchala et al. 2014; Javernick et al. 2014; Passalacqua et al. 2015). In 2015 the BFS acquired funding from the Otsego Lake Association for the purchase of an unmanned aerial vehicle (UAV) with a camera for environmental mapping purposes. This aerial vehicle can be controlled by software to fly a pre-determined path and capture images at a specified interval. Photographs captured with greater than 60% overlap can be mosaiced into a single image. In addition, software was available to recreate the three dimensional land surface from the images. We needed to tie together several systems to take advantage of the aerial imagery, including a total station to
survey ground control objects, differential GPS to provide geopositioning information, in addition to control over the flight path and camera orientation of the UAV. These are described briefly below.

The images acquired by UAV can be georeferenced (aligned to north and registered to widely used reference system such as latitude and longitude, or Universal Transverse Mercator) if georeferenced points appear in the images. For Wheeler’s farm, we used several ground control objects (also known as ground control points, or GCPs) constructed from yard sticks painted white and fastened to the ground in a cross pattern with a spike. We surveyed the GCPs with a Sokkia 530R total station and reflecting pole. The survey also recorded the location of two Magellan ProMark 3 GPS receivers. Post-processing the GPS data with GNSS Solutions software provided georeferenced locations with location uncertainties of a few cm. The GCP total station survey coordinates were then transformed into georeferenced coordinates using a two dimensional conformal coordinate transformation (accounts for scale difference, rotation and translation). The GCPs were identified in the photographs during mosaicing and three dimensional object reconstruction in Agisoft’s PhotoScan software. The software georeferenced the photos. In the final mosaic, each pixel was approximately 2.5 cm on the ground. Aerial imagery at this resolution is not readily available anywhere, and represents a significant mapping capability of UAVs. The mosaic could easily be compared to similarly rectified aerial imagery provided by New York State by overlaying the mosaic onto older imagery. This overlay appears below in Figure 4.
One of the byproducts of 3D object reconstruction in PhotoScan is an elevation point cloud consisting of geolocated pixels with associated color values. The point cloud was loaded into Global Mapper GIS software, and then gridded at 0.1 m spacing for visualization and topographic comparison with high resolution lidar elevation data from NYSDEC taken in 2007 at 2 m spacing. Vertical height changes of a few cm could be detected in the reconstructed 3D landscape (see Figure 5 for a visual comparison).

Initially, there was a difference in elevation projection of approximately 30 m between the 2007 and 2015 data sets. This is because the 2015 data were collected in an ellipsoid elevation reference frame, while the 2007 profile is in a geoid reference frame. We corrected the UAV to the geoid reference frame. A topographic profile was constructed from the 2007 lidar data and from the 2015 UAV elevation grid, and the two profiles were overlain on top of each other, shown in Figure 5 below. The green dashed line indicates the cross sectional area of the cutbank that was eroded from 2007 to 2015. Note that the 2007 profile is bare earth elevation, while the
profile from 2015 represents vegetation elevation. A bare earth elevation has all vegetation from the data set, and thus represents a ‘bare Earth’. This accounts for the substantial differences in elevation of the two data sets between 50m and 100m from the west end of the profile.

![Wheeler Field Elevation Comparison](image)

Figure 5. Comparison of the elevation of Butternut Creek in Wheeler’s field from 2007 to 2015. Green dashed line shows the eroded part of the cutbank from 2007 to 2015.

A significant goal of our survey was meant to answer the question: can small UAVs provide new and useful data? The answer is a resounding affirmative. Based on the excellent fit in co-location and proper elevation range when compared to other state published surveys, we think UAV mapping holds great promise for future data collection. The high data density from the UAV maps can be used to monitor erosion events down to a few cm in spatial extent. This level of resolution is at a scale where we can determine which process is the most important driver of channel migration. The orthophoto mosaic (all aerial images are merged into a single georeferenced image) which is part of the product from extracting elevation from the UAV survey captures details in plant communities, among other things, and thus the UAV could serve as a superb vegetation mapping tool.

Comparisons of the channel location over time

To expand the temporal coverage of our study of cutbank migration, we utilized New York State Department of Environmental Conservation’s (NYSDEC) online aerial imagery captured at various times in the past. These data can be accessed and downloaded for free ([http://www.orthos.dhses.ny.gov/](http://www.orthos.dhses.ny.gov/)). Errors in location are nominally 4 to 8 feet, and ground distance between pixels is 2 to 4 feet depending on the year the images were captured. While these errors may seem large, the movement of the bank over the last several years is several times these errors, and thus can be measured over time using this data set. We downloaded images from NYSDEC and then loaded them into Global Mapper, a GIS software (see Figure 6 below).
sketched the bank location for each time period. A line was drawn along the uppermost point of the cutbank on the west side of the creek in each of the orthoimages and the photomosaic. The line was drawn wherever the top of the cutbank location could be determined to reasonable accuracy from the images. See Figure 7 for the location of the cutbank over time.

![1994 Image](image1) ![2001 Image](image2)

**Figure 6.** Time series of aerial images for the cutbank on Wheeler’s Farm.

![2005 Image](image3) ![2010 Image](image4)

Sketches of the cutbank location reveal varying amounts of erosion occur along the entire length of the cutbank, with maximum amounts in the central portion and diminishing to nil at the ends of the cutbank arc (see Figure 6). To determine an average erosion rate, or more correctly, a bank migration rate, we measured the area of the cutbank that was eroded for the following time periods: 1994 to 2001; 2001 to 2005; 2005 to 2007; 2007 to 2010; 2010 to 2014; and 2014 to 2015. This information is summarized in Table 1. Note, for 2007, we used a high quality elevation data set which was developed after the major flooding of 2006. The data, called lidar elevation data, derives from a laser scanning device carried by an aircraft. Data posting was every 2 m, and vertical resolution is ~10 cm. Our UAV-derived elevation compared quite favorably with the lidar, as is shown in Figure 5 above. The migration rate is determined by dividing the total area lost by the length of the cutbank, divided by the time between aerial images \( \Delta t \). As an estimate of the length, one can divide the perimeter \( P \) of the area lost \( A \) by 2. So, the cutbank migration rate \( C \) is given by \( C = \frac{2A}{P\Delta t} \). Table 1 summarizes the measurements and calculations. Cutbank migration rates have varied from 0.13 to 1.68 m/yr (~5 inches to 5 feet per year).

Table 1. Eroded areas and migration rates of Butternut Creek over time.
<table>
<thead>
<tr>
<th>Years</th>
<th>Perimeter, m</th>
<th>Eroded area between sequential photos, m²</th>
<th>Average migration distance, m</th>
<th>Migration rate, m/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-2005</td>
<td>202.42</td>
<td>172.7</td>
<td>1.71</td>
<td>0.43</td>
</tr>
<tr>
<td>2005-2007</td>
<td>206.05</td>
<td>240.9</td>
<td>2.34</td>
<td>1.17</td>
</tr>
<tr>
<td>2007-2010</td>
<td>167.51</td>
<td>32.7</td>
<td>0.39</td>
<td>0.13</td>
</tr>
<tr>
<td>2010-2014</td>
<td>210.43</td>
<td>106.9</td>
<td>1.02</td>
<td>0.25</td>
</tr>
<tr>
<td>2014-2015</td>
<td>191.29</td>
<td>161.1</td>
<td>1.68</td>
<td>1.68</td>
</tr>
<tr>
<td>1994-2001</td>
<td>262.15</td>
<td>616</td>
<td>4.70</td>
<td>0.78</td>
</tr>
</tbody>
</table>

SUMMARY

This project investigated the potential of UAVs as a mapping tool. We were able to create a high fidelity map which included a georectified orthoimage and a digital terrain model of the farm field, riparian zone, and stream channel. The orthophoto mosaic was captured at a high resolution, about 2.5 cm/pixel. The vertical resolution of the digital terrain model was remarkable, capturing vegetation roughness changes of a few cm.

It was well known that Butternut Creek was migrating on Wheeler’s property, but quantification of migration was lacking. We utilized a time series of aerial imagery from NYS DEC to determine the cutbank migration rate for 6 time intervals since 1994. The rates vary substantially, by a factor of ~15. Some of this variability is likely due to significant flood events, though there are several contributing factors to erosion of stream cutbanks. These include the material in the cutbank, the location of the channel relative to the bank (for instance, at the outside bend of the channel), flood size and duration, animal activity (trails down to water), large woody debris in the channel, riparian vegetation, and freeze-thaw events (which can be quite vigorous on cutbanks). Which of these factors contribute most is an important question which we have not been able to answer yet. With these new monitoring tools (UAVs and repeat surveys), we should be able to address these issues, and provide more insight into how to control erosion of valuable farmland along the meandering reaches of local streams.

REFERENCES


